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(71) Applicant: OMRON CORPORATION
Kyoto-shi, Kyoto 616 (JP)

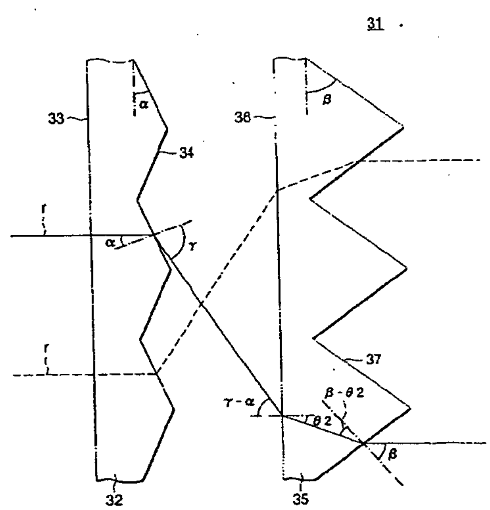
(72) Inventors:
- Aoyama, Shigeru, c/o Omron Corporation
Kyoto-shi, Kyoto (JP)
- Shinohara, Masayuki, c/o Omron Corporation
Kyoto-shi, Kyoto (JP)
- Yamashita, Tsukasa, c/o Omron Corporation
Kyoto-shi, Kyoto (JP)
- Kitajima, Hiroshi, c/o Omron Corporation
Kyoto-shi, Kyoto (JP)

(74) Representative: Calderbank, Thomas Roger et al
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

(54) **Optical path converting optical element, optical path converter, and optical projector and image display apparatus using said optical element**

(57) A first prism array (34) formed on a prism array plate (32) is arranged so as to confront a second prism array (37) formed on a prism array plate (35). When a light ray (r) that is parallel to an optical axis is transmitted through the first prism array, the light ray r enters into the second prism array (37) while refracted. The light ray that has been refracted by the second prism array (37) becomes an original light ray (r) that is parallel to the optical axis. Therefore, the light ray (r) that has passed through an optical path converting optical element (31) becomes a light ray (r) that is shifted in a direction perpendicular to the optical axis. As a result, the light is split and shuffled by the first prism array (34), so that a luminous intensity distribution thereof is uniformed.

FIG. 8



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arrays, each prism array having a plurality of prisms arrayed thereon, both prism arrays being disposed in such a manner that prism arraying directions thereof are substantially parallel to each other.

A mode of embodiment as recited in claim 2 is characterized in that in the optical path converting optical element according to claim 1, the two prism arrays are formed on front and back surfaces of a plate.

A mode of embodiment as recited in claim 3 is characterized in that in the optical path converting optical element according to claim 2, a shape of a prism array disposed on a light entering side and a refractive index of the plate are set in such a manner that a light ray whose optical path has been converted by the prism array disposed on the light entering side is totally reflected on a side surface of the plate.

A mode of embodiment as recited in claim 4 is characterized in that in the optical path converting optical element according to claim 1, one of the prism arrays is constructed of an interface between a first portion having a first refractive index and a second portion having a second refractive index; and the other prism array is constructed of a surface of the second portion.

A mode of embodiment as recited in claim 5 is characterized in that in the optical path converting optical element according to claim 4, a shape of a prism array disposed on a light entering side and a refractive index of the second portion are set in such a manner that a light ray whose optical path has been converted by the prism array disposed on the light entering side is totally reflected on a side surface of the second portion.

A mode of embodiment as recited in claim 6 is characterized in that in the optical path converting optical element according to claim 1, two plates are included, each plate having one surface thereof being flat and the other surface being formed into the prism array; a flat surface side of one of the plates is arranged so as to confront a prism array side of the other plate; a prism angle of a prism array disposed on a light entering side ranges from 35 to 45°; and a prism angle of a prism array disposed on a light emerging side ranges from 60 to 70°.

A mode of embodiment as recited in claim 7 is characterized in that in the optical path converting optical element according to claim 1, the prism arrays are arranged back to back; and prism angles of both prism arrays are set to 60° or more.

A mode of embodiment as recited in claim 8 is characterized in that in the optical path converting optical element according to claim 1, a surface of at least one prism array is flattened with a material having a refractive index different from a refractive index of a material of which the prism array is formed.

A mode of embodiment as recited in claim 9 is characterized in that in the optical path converting optical element according to claim 1, a light reflecting surface is formed between a first prism array and a second prism array in such a manner that an outer circumference of both prism arrays is enclosed.

A mode of embodiment as recited in claim 10 is characterized in that in the optical path converting optical element according to claim 1, a light shifting amount is egual to about 1/4 an effective area of an incident luminous flux.

A mode of embodiment as recited in claim 11 is characterized in that in the optical path converting optical element according to claim 1, a light shifting amount is equal to about 1/8 an effective area of an incident luminous flux.

An optical path converter as recited in claim 12 is characterized by comprising a plurality of optical path converting optical elements as recited in claim l are arranged so as to be arrayed along an optical path.

A mode of embodiment as recited in claim 13 is characterized in that in the optical path converter according to claim 12, the optical path converting optical element as recited in claim 8 is arranged on a light entering side; and the optical path converting optical element as recited in claim 9 is arranged on a light emerging side.

A mode of embodiment as recited in claim 14 is characterized in that in the optical path converter according to claim 12, prism arraying directions of at least portions of the optical path converting elements are different from each other.

An image dieplay apparatus as recited in claim 15 is characterized by comprising a light source, the optical path converting optical element as recited in claim 1, and an image display panel.

A mode of embodiment as recited in claim 16 is characterized in that in the image display apparatus according to claim 15, a projecting optical system for forming an image on the image display penal onto a screen is further arranged.

An optical projector as recited in claim 17 is characterized by comprising a light source and the optical path converting optical element as recited in claim 1.

Each of the optical path converting optical elements of the present invention has two prism arrays, and the prism arraying directions of both prism arrays are parallel to each other. Thus, when a light ray passes through a prism array on the light entering side, the light ray is refracted by the operation of such prism. The travelling direction of the light ray is changed from that of the light ray before injection by refraction at the prism array. Since the direction of the light ray has been changed, the light ray gradually deviates from the extension of the original light ray travelling direction by the time the light ray enters into the prism array on the light emerging side via the prism array on the light entering side. Thus, if the optical system is designed so that a light ray that has deviated from the extension of the original light ray travelling direction becomes a light ray that is parallel with the original light ray travelling direction after such light ray has passed through the prism array on the light emerging side, the light ray is shifted parallelly by passing through the optical path converting op-

mode of embodiment of the present invention.

Fig. 18 is a schematic side view showing an optical path converting optical element, which is still another mode of embodiment of the present invention.

Fig. 19 is a schematic side view showing an optical path converting optical element, which is still another mode of embodiment of the present invention.

Fig. 20 is a schematic side view showing an optical path converting optical element, which is still another mode of embodiment of the present invention.

Fig. 21 is a schematic diagram showing an optical path converter, which is still another mode of embodiment of the present invention.

Figs. 22(a), 22(b) and 22(c) are diagrams illustrative of an operation of the optical path converter shown in Fig. 21.

Fig. 23 is a perspective view showing an optical path converter, which is still another mode of embodiment of the present invention.

Fig. 24 is a perspective view showing an optical path converter, which is still another mode of embodiment of the present invention.

Fig. 25 is a perspective view showing a prism array plate in which prisms are arrayed on a two-dimensional basis.

Fig. 26 is a schematic diagram showing a configuration of an optical projector, which is still another mode of embodiment of the present invention.

Fig. 27 is a schematic diagram showing a configuration of an optical projector, which is still another mode of embodiment of the present invention.

Fig. 28 is a partially cutaway enlarged sectional view showing an image display apparatus, which is still another mode of embodiment of the present invention.

Fig. 29 is a functional block diagram of the image display apparatus shown in Fig. 28.

Fig. 30 is a partially cutaway enlarged sectional view showing an image display apparatus, which is still another mode of embodiment of the present invention.

Fig. 31 is a schematic diagram showing a configuration of a liquid crystal projector, which is still another mode of embodiment of the present invention.

(First mode of embodiment)

Fig. 6 is a schematic side view showing a configuration of an optical path converting optical element 31, which is a mode of embodiment of the present invention. In this mode of embodiment, the optical path converting optical element 31 is formed of two prism array plates 32, 35. As shown in Fig. 7, the prism array plate 32 is formed so that a first flat surface 33 is arranged on one surface thereof and a first prism array 34 having an array of one-dimensional prisms is arranged on the other surface thereof. Similarly, the prism array plate 35 is formed so that a second flat surface 36 is arranged on one surface thereof and a second prism array 37 having an array of one-dimensional prisms is arranged on the other surface thereof. The prism array plate 32 having both the first prism array 34 and the first flat surface 33 is disposed on a light entering side, whereas the prism array plate 35 having both the second prism array 37 and the second flat surface 36 is disposed on a light emerging aide. The first prism array 34 arranged on the prism array plate 32 that is disposed on the light entering side confronts the second flat surface 36 arranged on the prism array 35 that is disposed on the light emerging side. The prism array plates 32, 35 are made of glass, transparent resin or a composite body of glass and transparent resin. The prisms formed on the first and second prism arrays 34, 37 are pitched at the same interval and are disposed so that the prism arraying directions are the same in both prism arrays 34, 37. To simply the explanation, the refractive indices n of both prism array plates 32, 35 are set to the same value, but it is not necessarily required that both prism array plates be made of materials having the same refractive index.

Thus, as shown in Fig. 8, when a light ray r that travels parallel to the optical axis enters into the prism array plate 32 from the first flat surface 33, such light ray r is refracted at the time of emerging from the first prism array 34 and enters into the prism array plate 35 disposed on the light emerging side obliquely from the second flat surface 36. The light ray r that has entered into the prism array plate 35 is not only deflected at the time of obliquely entering into the second flat surface 36, but also deflected at the time of obliquely emerging from the second prism array 37. Here, the first prism array 34 and the second prism array 37 are arranged in such a manner that the direction of inclination of the region in the first prism array 34 through which the light ray r passes is opposite to the direction of inclination of the region in the second prism array 37 through which the light ray r passes. That is, the shapes (prism angles α, β) of the first and second prism array plates 32, 35 are designed so that a light ray that has passed through both prism array plates 32, 35 emerges parallel to the optical axis as the original incident light ray. That is, the light ray r that is parallel to the optical axis has the travelling direction thereof not changed but only parallelly shifted even after the light ray r has passed through the optical path converting optical element 31. As a result, the light diffusing angle becomes very small. Further, as shown in Fig. 8, light rays that have entered parallel to the optical axis are split into respective prism regions by the first prism array 34 and are rearranged in directions perpendicular to the optical path (shuffled) every light ray r passing through the corresponding region while parallelly shifted. Therefore, when light rays r having such ununiform luminous intensity distribution as shown, e. g., in Fig. 2 (a) pass through the optical path converting optical element 31, the optical paths thereof are converted in such a manner that the distances from the optical axis are shuffled. As a result, the luminous inteneity distribution of such light rays r are uniformed. Therefore, by employing such optical path converting optical ele-

(Fourth mode of embodiment)

An optical path converting optical element 42 shown in Fig. 12 is also a modification of the first mode of embodiment. This optical path converting optical element 42 is formed by arranging the prism array plate 32 so as to confront the prism array plate 35 while interposing a space therebetween, and by arranging a framelike light reflecting plate (inner surface mirror) 43 so as to enclose the space between both prism array plates 32, 35. By arranging the light reflecting plate 43 between the prism array plates 32, 35, a light ray having obliquely emerged from the prism array plate 32 can be reflected by the light reflecting plate 43. As a result, light utilization efficiency can be improved by preventing leakage of light. Further, both prism array plates 32, 35 can be integrated by the light reflecting plate 43.

(Fifth mode of embodiment)

Fig. 13 is a schematic side view showing an optical path converting optical element 44, which is still another mode of embodiment of the present invention. This optical path converting optical element 44 has the first and second prism arrays 34, 37 formed on both front and back surfaces of a plate 45 whose refractive index is n. The first and second prism arrays 34, 37 are constructed of prisms that are pitched at the same interval. The prism angles α of both prism arrays 34, 37 are set to 60° or more.

Thus, as shown in Fig. 13, a light ray r having entered into the first prism array 34 parallel to the optical axis enters into the plate 45 while refracted at the first prism array 34, and then emerges from the second prism array 37. Here, if the thickness of the plate 45 and the positions of the first and second prism arrays 34, 37 are defined in such a manner that an inclined region of the first prism array 34 through which the light ray r passes extends parallel to an inclined region of the second prism array 37 through which the light ray r passes, then the light ray r that has entered parallel to the optical axis is shifted in a direction perpendicular to the optical axis and emerges parallel to the optical axis since the prism angles α of the first and second prism arrays 34, 37 are the same. Therefore, this optical path converting optical element 44 also can provide a uniform luminous intensity distribution without increasing the light diffusing angle.

Here, the condition that a light ray refracted at one inclined region of the first prism array 34 enters into an inclined region of the second prism array 37 having the same angle of inclination and emerges parallel to the optical axis can be expressed in the following inequality (7).

$$\theta_2 > 90° - \alpha \qquad (7)$$

where the angle of emergence of the light ray r in the first prism array 34 is θ_2; and the prism angle of the first and second prism arrays is α. Here, the angle or emergence θ_2 is given as

$$\theta_2 = \alpha - \sin_{-1} (\sin\alpha / n) \qquad (8)$$

Hence, the aforementioned inequality (7) can be written as

$$\alpha - \sin_{-1} (\sin\alpha / n) > 90° - \alpha$$

Fig. 14 shows the range of the prism angle α in function of the refractive index n. As can be understood from Fig. 14, when the refractive index n is smaller than 1.6, the range of the prism angle α becomes, as described above, 60° or more.

Figs. 15 (a) to 15 (e) illustrate a principle of how a luminous intensity distribution is uniformed by the thus constructed optical path converting optical element 44. Fig. 15 (a) shows an ununiform luminous intensity distribution of light before the light enters into the optical path converting optical element 44; Fig. 15 (b) shows a light ray shifting in an upper left direction and in an upper right direction after having passed through the optical path converting optical element 44; Figs. 15 (c) and (d) show luminous intensity distributions formed respectively by a light ray having shifted leftward and a light ray having shifted rightward; Fig. 15 (e) shows a luminous intensity distribution of the light that has passed through the optical path converting optical element, the luminous intensity distribution being formed by synthesizing the luminous intensity distributions shown in Figs. 15 (c) and (d).

How a luminous intensity distribution is uniformed will be described with reference to Figs. 15 (a) to 15 (e). When a light ray having a luminous intensity distribution 47 such as shown in Fig. 15 (a) is shifted leftward by the optical path converting optical element 44, the luminous intensity distribution 47 shown in Fig. 15 (a) seems to be shifted leftward directly. However, the light ray refracted leftward at the left end portion of the first prism array 34 returns rightward while totally reflected at the outer circumference 46 of the optical path converting optical element 44. As a result, a luminous intensity distribution 48a has a portion thereof indicated by the broken line in Fig. 15 (c) so turned twice as indicated by the solid line. Similarly, a luminous intensity distribution 48b of the light ray shifted rightward by the optical path converting optical element 44 becomes as shown in Fig. 15 (d). Since the light ray shiftod leftward and the light ray shifted rightward emerge from the optical path converting optical element 44, the luminous intensity distribution of the light rays emerging from the optical path converting optical element 44 becomes a luminous intensity

(Eleventh mode of embodiment)

Fig. 21 is a schematic view showing an optical path converter 62, which is still another mode of embodiment of the present invention. This optical path converter 62 has a first optical path converting optical element 63 and a second optical path converting optical element 64 of the present invention arranged along the optical path, and has the prism arraying directions of both optical path converting optical elements 63, 64 disposed so as to be parallel to each other. By using a plurality of optical path converting optical elements 63, 64, if a luminous intensity distribution provided by the first optical path converting optical element 63 is not adequately uniform, a more uniform luminous intensity distribution can be provided by the second optical path converting optical element 64.

The first optical path converting optical element 63 shifts a light ray by an amount L/4 when it is assumed that the width of an effective area into which a luminous flux enters parallel to the optical axis is L. Similarly, the second optical path converting optical element 64 shifts a light ray by an amount L/8. Thus, for example, as shown in Fig. 22 (a), a luminous flux having an ununiform luminous intensity distribution enters into the first optical path converting optical element 63, the luminous intensity distribution of such luminous flux has been uniformed by passing through the first optical path converting optical element 63 as shown in Fig. 22 (b). However, even after having passed through the first optical path converting optical element 63, nonuniformity exhibited at a cycle of L/2 still remains in the thus uniformed luminous intensity distribution. such nonuniformity exhibited at a cycle of L/2 is rectified by the second optical path converting optical element 64 that is designed so that a light ray is shifted half the shifting amount of the first optical path converting optical element 63. The luminous intensity distribution of the luminous flux that has passed through the second optical path converting optical element 64 becomes as uniform as shown in Fig. 22 (c).

(Twelfth mode of embodiment)

Fig. 23 is a perspective view showing an optical path converter 65, which is still another mode of embodiment of the present invention. This optical path converter 65 is characterized as making the prism arraying direction of a first optical path converting optical element 66 and that of a second optical path converting optical element 67 different from each other, the first and second optical path converting optical elements 66, 67 being arranged parallel to the optical path. In the mode of embodiment shown in Fig. 23 in particular, both prism arraying directions are set to be orthogonal to each other. That is, the first prism array 34 and the second prism array 37 are formed so that the prism arraying directions thereof are parallel to each other on both surfaces of the first optical path converting optical element 66, whereas a third prism array 68 and a fourth prism array 69 are formed so that the prism arraying directions thereof are parallel to each other on both surfaces of the second optical path converting optical element 67. The first optical path converting optical element 66 and the second optical path converting optical element 67 are disposed so that the prism arraying direction of the first and second prism arrays 34, 37 and that of the third and fourth prism arrays 68, 69 are orthogonal to each other. Further, while there is a space between the first and second optical path converting optical elements 66, 67 in Fig. 23, a transparent adhesive whose refractive index is lower than that of the optical path converting optical elements 66, 67 may be loaded to such space.

Thus, according to the optical path converter 65, a direction in which a light ray is shifted by the first optical path converting optical element 66 is different from a direction in which a light ray is shifted by the second optical path converting optical element 67. Therefore, light rays can be shifted and synthesized on a two-dimensional basis, so that the luminous intensity distribution thereof can be uniformed on a two-dimensional basis.

(Thirteenth mode of embodiment)

An optical path converter 70 shown in Fig. 24 is a modification of the twelfth mode of embodiment. The first optical path converting optical element is formed of the first prism array 34 and the second prism array 37 that confront each other so that the prism arraying directions thereof are parallel to each other, whereas the second optical path converting optical element is formed of the third prism array 68 and the fourth prism array 69 that confront each other so that the prism arraying directions thereof are parallel to each other. The prism arraying direction of the first optical path converting optical element and that of the second optical path converting optical element are orthogonal to each other. More specifically, the first prism array 34 of the first optical path converting optical element is arranged on the inner surface of a plate 71 that is on an outer side; the second prism array 37 of the first optical path converting optical element and the third prism array 68 of the second optical path converting optical element are arranged back to back on both surfaces of a plate 72 that is in the middle in such a manner that the prism arraying directions thereof are orthogonal to each other; and the fourth prism array 69 of the second optical path converting optical element is arranged on the inner surface of a plate 73 that is on an outer side. A light reflecting plate (not shown) covers an outer circumference that extends from the plate 71 on the outer side to the plate 73 on the outer side. In the thus constructed optical path converter 70 also, the luminous intensity distribution of a light ray can be uniformed on a two-dimensional basis without increasing the diffusing angle of the light ray.

densed onto pixel holes of the liquid crystal display panel 83 by the microlens 104, and pass through the pixel holes and emerge toward the front of the liquid crystal display panel 83.

Therefore, according to this mode of embodiment, light utilization efficiency can be improved, which in turn allows an image display apparatus with high luminance and uniform luminance distribution to be manufactured.

(Nineteenth mode of embodiment)

Fig. 31 is a schematic diagram showing a configuration of a liquid crystal projector 105 using the optical path converting optical element 84 of the present invention. This liquid crystal projector 105 is characterized as arranging the optical path converting optical element 84 (or an optical path converter) and the microlens array 104 ahead of a subsurface illuminator 108 consisting of a lamp 106 and a parabolic reflector 107, arranging the liquid crystal display panel 83 ahead of the optical path converting optical element 84 and the microlens array 104, and arranging a projector lens 109 ahead of the liquid crystal display panel 63.

Thus, light rays r that have been injected rearward from the lamp 106 and reflected by the reflector 107 are projected onto the optical path converting optical element 84 as substantially parallel light rays, have the luminous intensity distribution thereof uniformed by the optical path converting optical element 84, and are thereafter condensed onto the pixel holes of the liquid crystal display panel 83 by the microlens array 104. The light rays that have passed through the liquid crystal display panel 83 generate an image on a screen 110 through the projector lens 109.

The thus constructed liquid crystal projector 105 can provide uniform and bright images. In addition, unlike the conventional liquid crystal projector, a complicated optical system including an integrator lens, a field lens, and a condenser lens can be dispensed with, which in turn contributes to reducing the cost of manufacture.

(Advantage of the Invention)

As described above, an optical path converting optical element of the present invention allows a luminous flux to be split and the respective split light rays to be shuffled. Therefore, a luminous intensity distribution can be uniformed without increasing the light diffusing angle. In addition, an optical path converter of the present invention are formed of a plurality of optical path converting optical elements. Therefore, a luminous intensity distribution can be better uniformed; and in addition, a luminous intensity distribution can be uniformed on a two-dimensional basis. Therefore, when the optical path converter of the present invention is applied to image display apparatuses or the like, uniform images whose luminance distributions are uniformed can be provided.

Claims

1. An optical path converting optical element comprising two prism arrays, each prism array having a plurality of prisms arrayed in a prism arraying direction, both prism arrays being disposed in such a manner that the prism arraying directions of the prism arrays are substantially parallel to each other.

2. An optical path converting optical element according to claim 1, wherein the two prism arrays are formed respectively on front and back surfaces of a plate.

3. An optical path converting optical element according to claim 2, wherein a shape of a prism array disposed on a light entering side and a refractive index of the plate are set in such a manner that a light ray whose optical path has been converted by the prism array disposed on the light entering side is totally reflected on a side surface of the plate.

4. An optical path converting optical element according to claim 1, wherein one of the prism arrays is constructed of an interface between a first portion having a first refractive index and a second portion having a second refractive index; and the other prism array is constructed of a surface of the second portion.

5. An optical path converting optical element according to claim 4, wherein a shape of a prism array disposed on a light entering side and a refractive index of the second portion are set in such a manner that a light ray whose optical path has been converted by the prism array disposed on the light entering side is totally reflected on a side surface of the second portion.

6. An optical path converting optical element according to claim 1, comprising two plates, each plate having one surface thereof being flat and the other surface being formed into the prism array, a flat surface side of one of the plates being arranged so as to confront a prism array side of the other plate, a prism angle of a prism array disposed on a light entering side ranging from 35 to 45°, a prism angle of a prism array disposed on a light emerging side ranging from 60 to 70°.

7. An optical path converting optical element according to claim 1, wherein the prism arrays are arranged back to back; and prism angles of both prism arrays are set to 60° or more.

8. An optical path converting optical element according to claim 1, wherein a surface of at least one prism array is flattened with a material having a re-

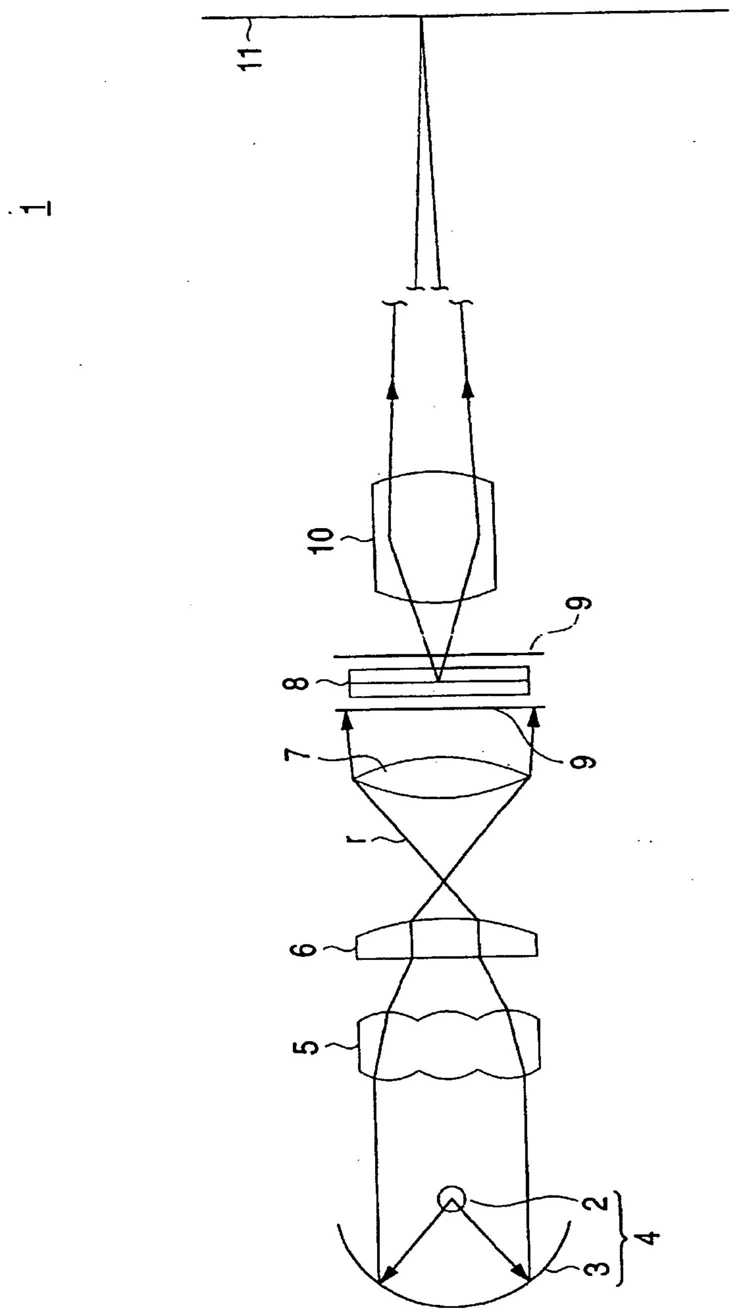


FIG. 1

FIG. 3

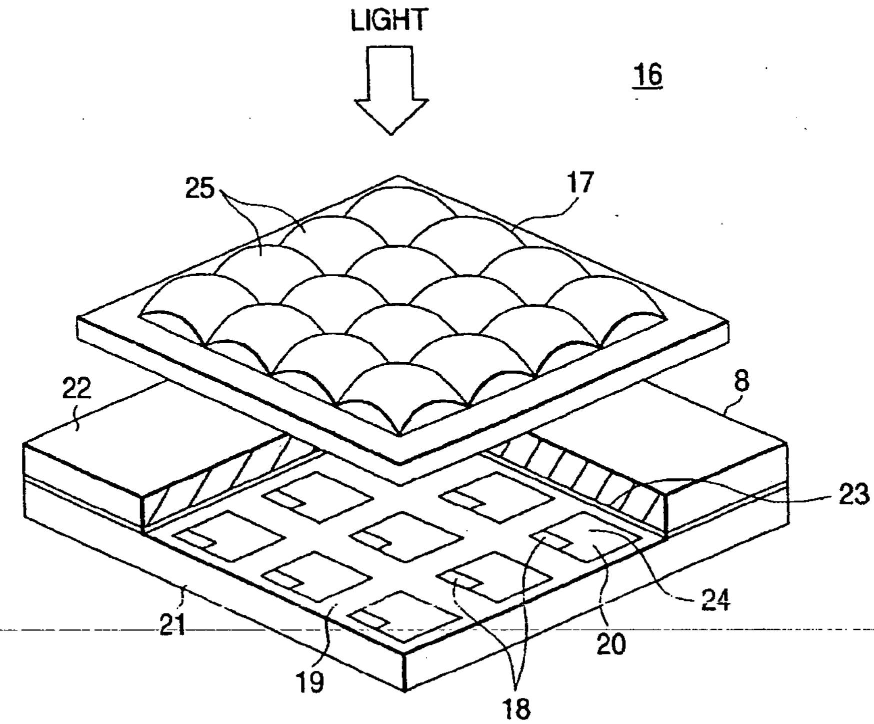


FIG. 4

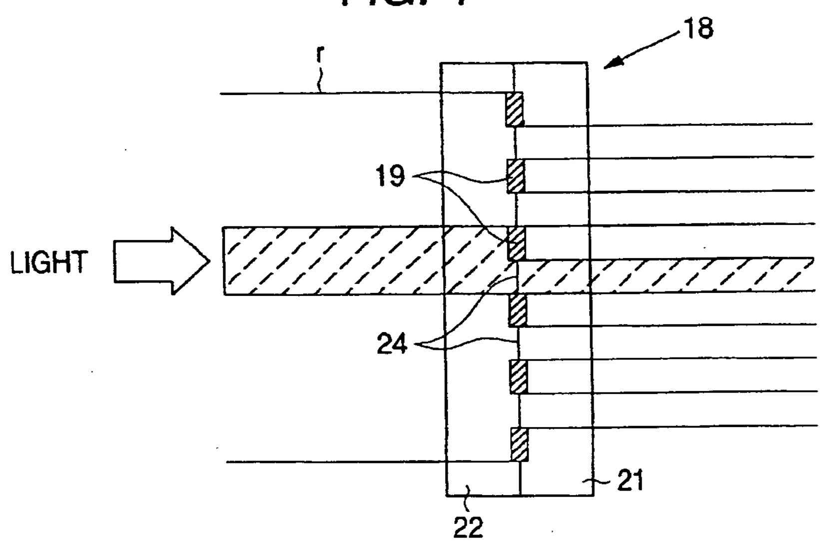


FIG. 6

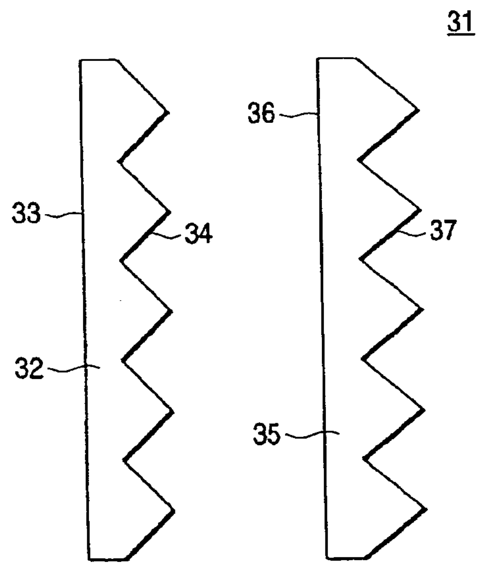


FIG. 7

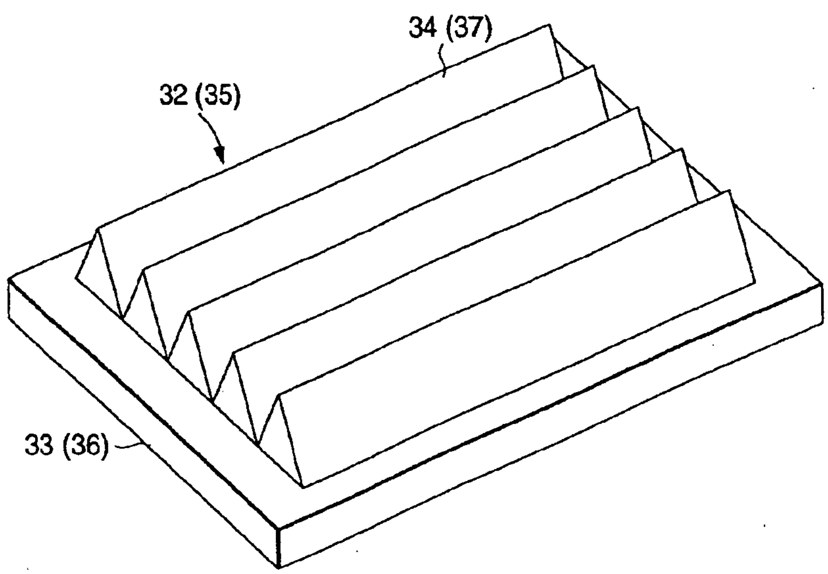


FIG. 9

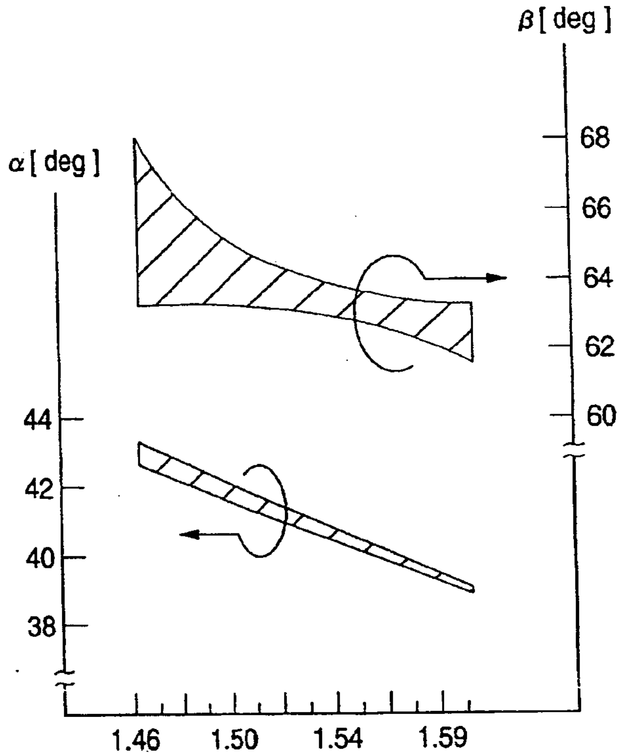

β [deg]
68
66
64
62
60
α [deg]
44
42
40
38
1.46
1.50
1.54
1.59

FIG. 10

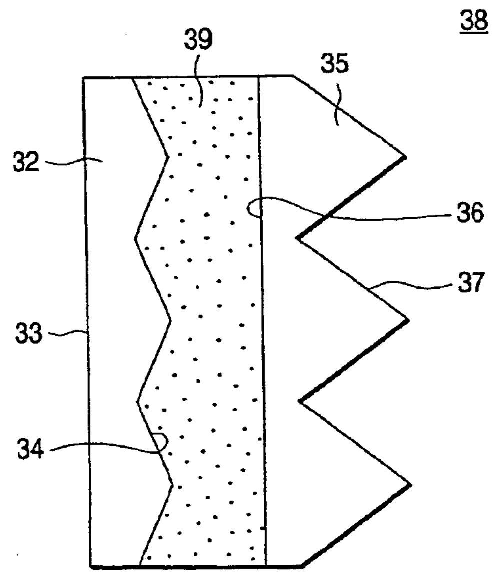

38
39
35
32
36
37
33
34

FIG. 13

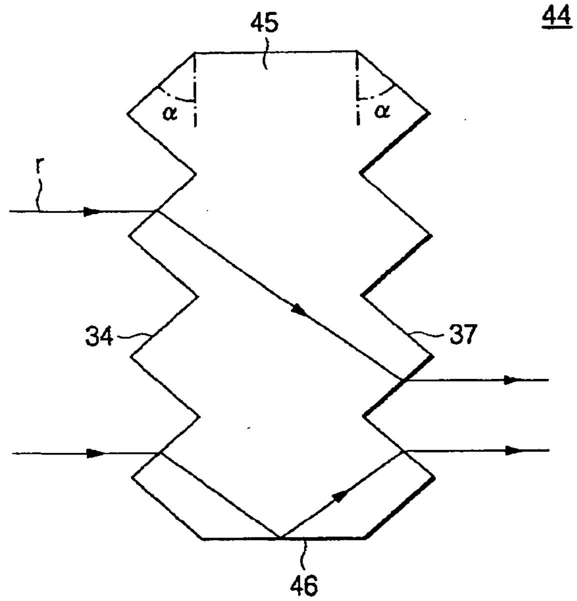

44
45
α
α
r
34
37
46

FIG. 14

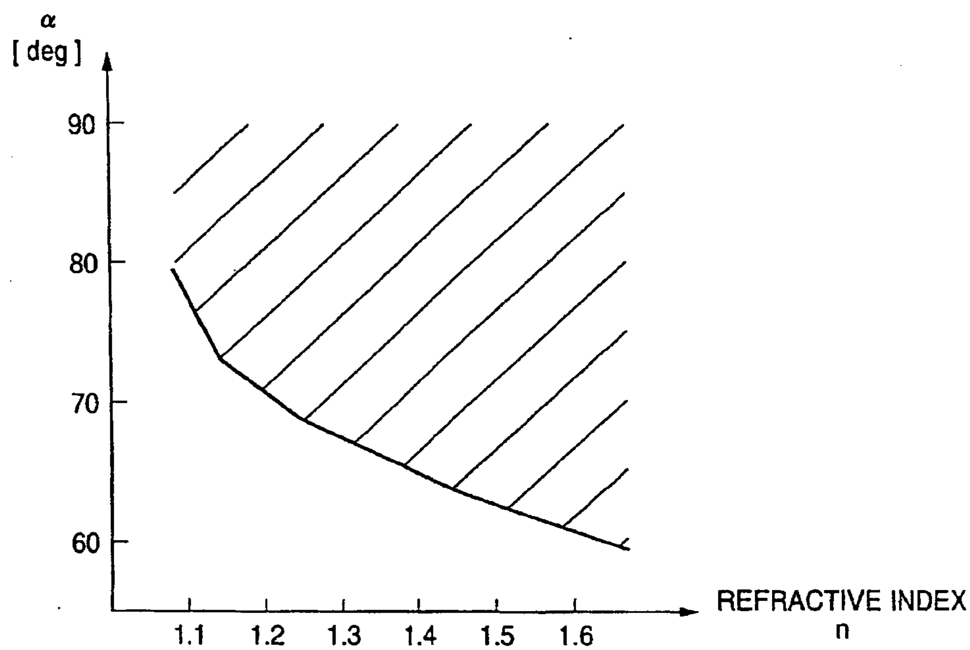

α
[deg]
90
80
70
60
1.1
1.2
1.3
1.4
1.5
1.6
REFRACTIVE INDEX
n

FIG. 16

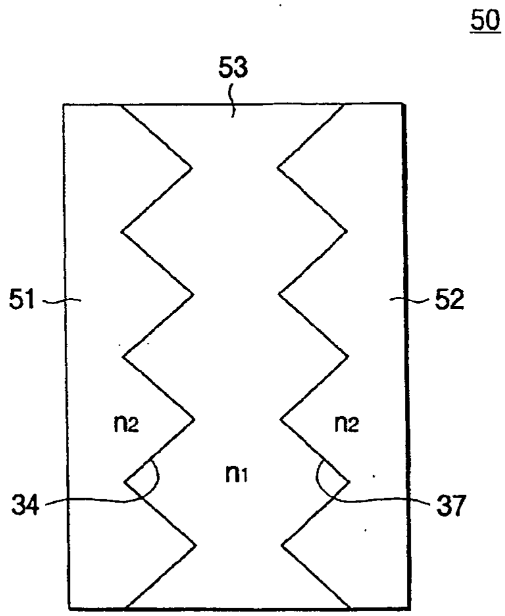


FIG. 17

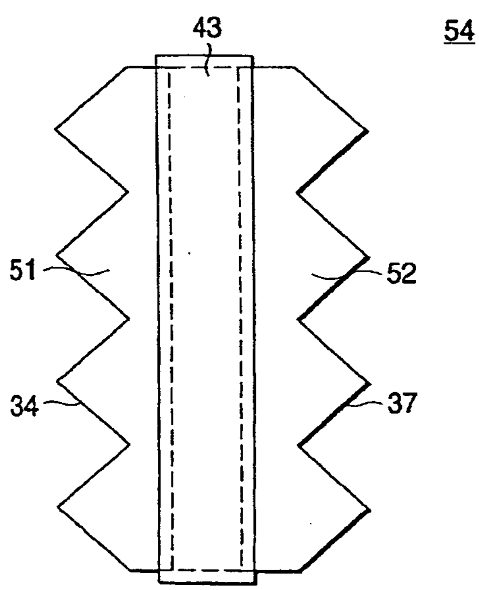


FIG. 21

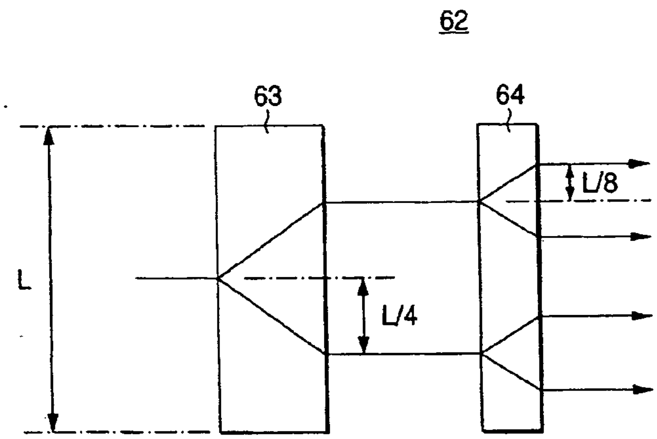


FIG. 22 (a)

FIG. 22 (b)

FIG. 22 (c)

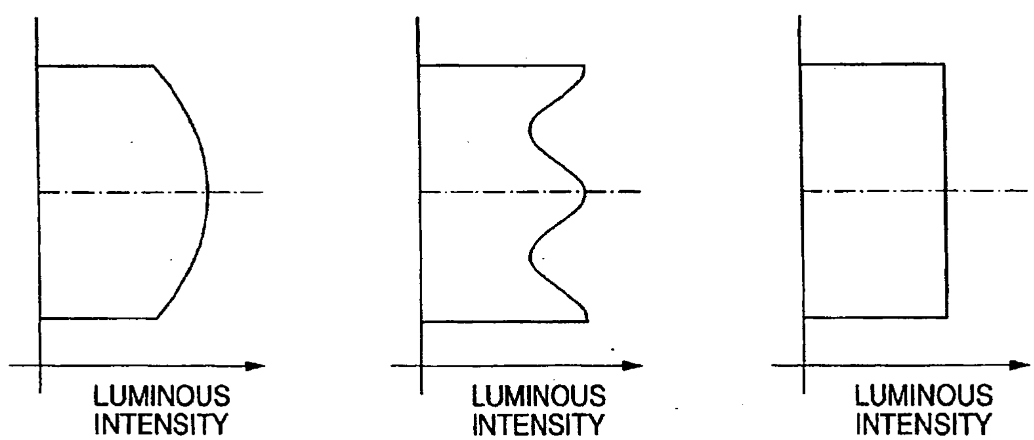


FIG. 25

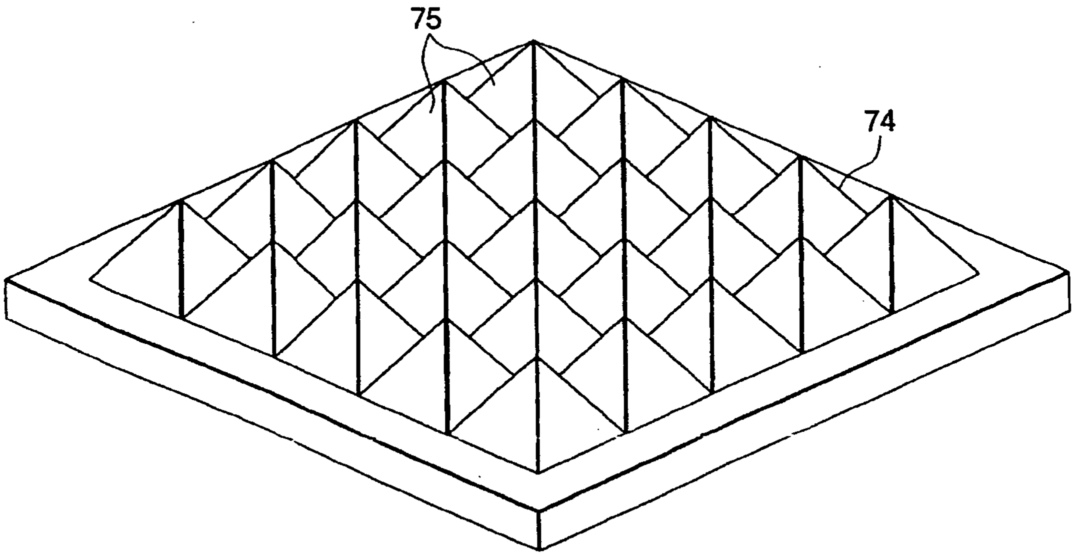
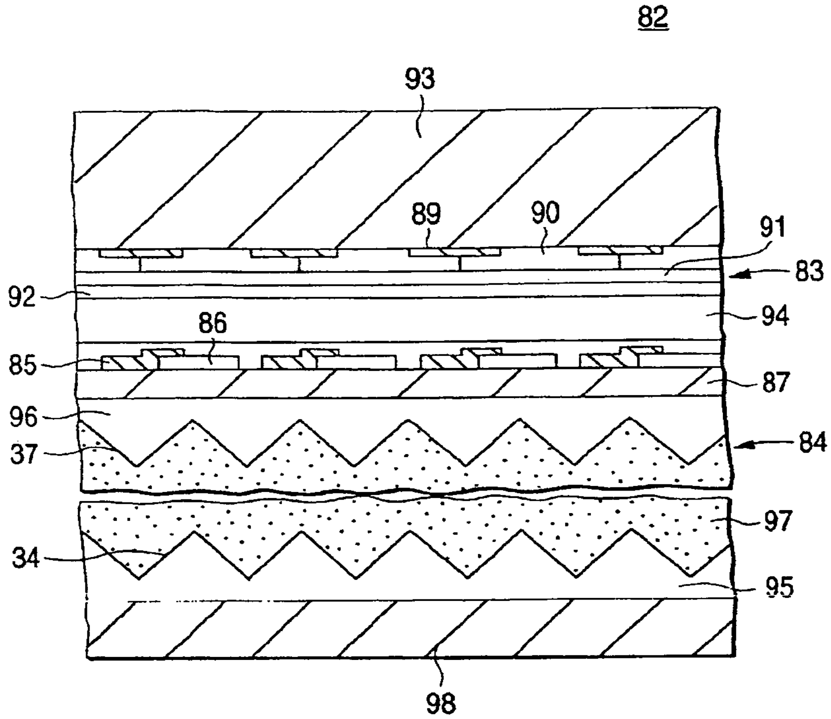


FIG. 28


82
93
89
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91
83
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86
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37
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98

FIG. 29

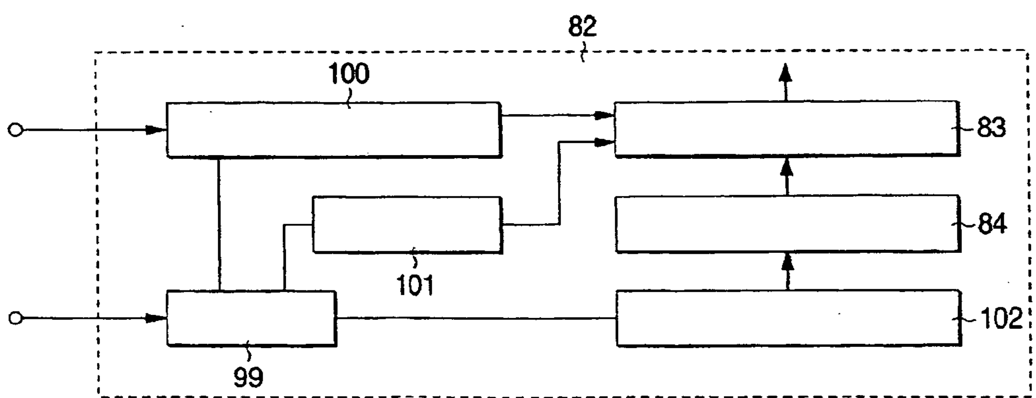
82
100
83
84
101
102
99

FIG. 31

105